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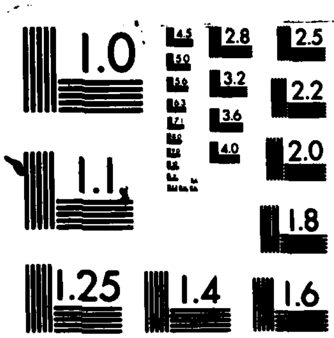

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: M22/84	2. GOVT ACCESSION NO.: AD-A140763
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): A Brief History of the Use of Simulation Techniques in Training and Performance Assessment	5. TYPE OF REPORT & PERIOD COVERED: Manuscript
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Earl S. Stein and John L. Kobrick	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army Research Institute of Environmental Medicine, Natick, MA 01760	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE: 27 April 1984
	13. NUMBER OF PAGES: 16
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Approved for public release; distribution is unlimited.

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Simulation, war gaming, technology, weapons

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Simulation might be generally viewed as a form of controlled fantasy with a finite and functional purpose. Fantasy and imagination are universal features of human life, and have several constructive aspects, including the release of tension. Simulation could very likely have been used in crude form by primitive man, as a form of protection. An unarmed cave-person threatened by an animal - or a more aggressive cave-person - might attempt to convince the opponent that attack was inadvisable. An axe might be simulated by use of a

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A Brief History of the Use of Simulation Techniques in Training and Performance Assessment

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Simulation might be generally viewed as a form of controlled fantasy with a finite and functional purpose. Fantasy and imagination are universal features of human life, and have several constructive aspects, including the release of tension. Simulation could very likely have been used in crude form by primitive man, as a form of protection. An unarmed cave-person threatened by an animal - or a more aggressive cave-person - might attempt to convince the opponent that attack was inadvisable. An axe might be simulated by use of a stick, or even by a shadow in the right lighting. Later when firearms became available, the armies of the time, whose logistics could only equip those actually in combat, often received their initial training with that universal weapons simulator - the stick.

As technology and the magnitude of warfare grew, simulations also increased in size and complexity. During the nineteenth century, war gaming developed as an important and cost-effective technique for

training; and, more importantly, for use as an aid in command decisions. War gaming provided an innovative opportunity for staff interaction, since it allowed an overview of both the resources available and the limitations and constraints of the terrain. It also provided a way to compare potential courses of action. The Prussian general staff was particularly effective in the use of these methods, and carried their skills into German military operations in the First World War. The Japanese general staff developed war game simulation to a fine art between the World Wars. Their immense success at Pearl Harbor was due partly to the meticulous planning and war gaming which they had conducted prior to the attack.

Traditional war gaming might be viewed as a low-technology form of simulation involving boards, player pieces and detailed rules. It focuses on the higher cognitive functions of planning and decision making, but does not require the kinds of physical coordination characteristic of high-technology systems.

The advent of aviation in the early part of the twentieth century, coupled with our national industrialization, generated new requirements for training in highly complex person-machine environments. Out of this need, the seeds of high-technology simulation were born. Aviation involved a multi-task situation in which both task sharing and prioritization were essential for

survival. During the build-up for World War I, the frequency of fatalities in flight training made it clear that alternative techniques were required. Out of this need, primitive flight simulators evolved. Although the emphasis was still on training rather than on research, early person-machine simulations began their evolution. World War I vintage flight simulation was a low-technology affair at best, in which simulators were constructed out of materials at hand - in many cases, little more than a stick and a chair. Army Air Corps trainers at the time probably would have given up simulation if it hadn't helped them in some way, probably by reducing the death and destruction occurring in primary flight training.

Flight simulation has provided the basis for development of high technology training systems, which in turn have evolved into viable test beds for assessing human performance. Simulation for training has always had to keep abreast of aviation technology, and during the post-World War I period resulted in the design of the first truly sophisticated trainer, the Link I. This device, affectionately nicknamed "the box", incorporated both pilot information displays and a basic movement platform, which would respond to the pilot's control inputs and provide feedback on the results of the pilot's actions. The Link I was the forerunner of a long line of flight simulators ranging in sophistication from moderate to high levels of realism. The more recent flight simulators have provided amazing research

potential for dealing with questions of both person-machine relationships and person-to-person performance in a crew or team operation.

Prior to and during World War II, the German Army evaluated leaders and/or officer candidates using an assessment center concept. This involved a series of simulations and other techniques. The assessment center performed personnel evaluations using a unique blend of traditional psychological assessment tools, such as paper-and-pencil tests, along with a series of situational exercises, or mini-simulations. In similar fashion, the US Army Office of Strategic Services (OSS) in 1942 established an assessment center somewhere in Virginia at a location called "Station S." A staff of psychologists and psychiatrists, many of whom served as privates, were tasked to develop simulation testing scenarios for use in selecting OSS agents for overseas duty. This project was mounted in the hope that the assessment center model could produce a reliable and valid method for predicting the success of OSS agents. However, the criteria of success were never properly defined. In a book written later by the OSS Assessment Center Staff (1948), they admitted that validity was difficult to determine, since many agents who had passed successfully through the simulated stressors at Station S never returned from their assignments overseas.

The US Army has experimented with assessment centers and mini-simulations over the years. The so-called Leader Reaction Course, which is run at many Army service schools, was modeled after the OSS version described above. In this application, young officers and NCO's are instructed to solve a problem within a limited time using a set of resources and people, which are provided. For example, a classic problem is to get a squad of soldiers across a stream. Performance measurement is usually done by use of a rating scale administered by one observer/rater, which makes reliability somewhat questionable. In contrast, however, many assessment center simulations employ multiple raters to obtain their measurements.

The Army operated an assessment research center at Fort McClellan in the 1960's , and also one at Fort Benning from 1972 to 1974. The Center at Fort Benning was organized as a pilot research project sponsored by the Infantry School and supported by the Army Research Institute for the Behavioral and Social Sciences (ARI). It was operated primarily by and for Infantrymen. Although these infantry personnel knew very little about behavioral measurement, they had much to offer toward the development of simulations. Based on the old Army tradition of making do with what is available, the infantry assessors designed simulations for a wide variety of leader behaviors ranging from administration to leadership in field combat. Role-playing exercises and group decision-making situations were developed. In the

process of formulating the necessary multiple rating techniques, problems of inter-rater reliability arose. Reliability ratings ranged from low to moderate at best, but improved suddenly in one day after the Center commander expressed his concern about this problem , and indicated that all of the observers would in their turn be rated for efficiency by him. This type of influence, which was well-meant but misguided, diminished the quality of, or even may have totally invalidated the research.

Although research on assessment centers in the Army did not result in long-term prediction models, still it did much to support the use of simulation for training purposes. It is important to note here that other allied military forces, particularly the Israeli and British Armies, have become very interested in assessment simulations. The British screen all of their enlistees before assigning them to specialized training. They also use assessment centers to select candidates for the National Military College at Sandhurst. Although the US Army has not generally adopted the use of assessment centers, simulation techniques certainly have been employed by others in the training and research communities.

It is fair to say that the Army has long-standing experience in the use of simulation. Besides flight simulation, which plays a major role in the training of Army aviators, the Army has created a series

of varied simulations. Over the past fifteen years, a family of war games for battle simulation has been developed by the Combined Arms Testing and Research and Development Agency (CATRADA) at Fort Leavenworth, KA. These war games, referred to as Battle Simulations, range in scope from squad to brigade levels. Much of the research done with battle simulation has focused on leader decision-making and inter-staff communication. Battle simulations offer a fertile ground for evaluating the impact of various stressors on battalion and brigade command groups whose behavior in simulation mirrors quite well what personnel would be doing in an actual field tactical operations center (TOC). Despite the fact that battle simulations are conducted indoors in relative comfort by officers and selected NCO's, it is amazing how involved the participants can become. It is not unusual to find players still in a game "set" as much as one hour after an exercise is completed. Figures 1 and 2 show a group of company team commanders from the Blue and Red Forces heavily engaged in a Pegasus Battle Simulation which was run by the 2070th USAR School at Fort Belvoir. In Figure 3, the S-3 briefs the staff on the concept of the operation for defense of the Fulda Gap.

Figures 1, 2 and 3 about here

Armies historically have trained in the field in a manner little different from the childhood games of "cops and robbers"; i.e., "bang-

bang, you're dead." The field training exercise has always been a ritual of discomfort, in which troops characteristically became convinced that their primary mission was learning to be miserable, a skill that every soldier is certain was issued to him at induction and that, therefore,he does not have to learn. However, in the 1970's a movement developed to change the concept of field training to include use of a simulation system based on more finite rules of casualty assessment. This system using reinforcement learning principles was designed to teach small units to perform combat operations in a relatively realistic simulation without involving the obvious hazards of actual warfare. A group of these simulations became known by the generic term Engagement Simulation (ES). The first one, called "SCOPES", was developed by a military joint working group which included combat veterans assigned to the Training and Doctrine Command (TRADOC) at Fort Eustis, as well as psychologists on the staff of the Army Research Institute for the Behavioral and Social Sciences (ARI).

Engagement simulation exercises differed from field training exercises (FTX's) in terms of how casualties were assessed, and how this assessment influenced troop motivation. Rather than using umpires making arbitrary judgments concerning simulated life and death conditions, ES employed a complex system of controllers, radio communication, telescopic sights and identification numbers for the

personnel involved in the exercise. The basic concept underlying this low-technology simulation was that if an infantryman could be detected, then he could be killed. Every soldier wore an identification number derived from a set of key numbers assigned randomly to the opposing forces. If an enemy soldier could read an identification number through a low-power telescopic sight and then could fire his weapon, the person receiving the fire and wearing the corresponding identification number was considered to be killed in action. He was informed of this by the Controller with his unit, who received the message by radio from his counterpart on the opposing force.

Researchers and training developers have been consistently amazed by the degree to which soldiers develop feelings of involvement in ES exercises. Commanders of units involved in the development of ES have often commented anecdotally that during ES exercises both discipline problems and AWOL rate have declined. This may have been due to increased motivation, identification and feelings of involvment with the exercise, or it may have been the novelty of the ES Program.

ES was destined to grow in use and application in the US Army. It expanded beyond infantry to include armor and combined arms teams, and eventually was retitled "Realtrain". Artillery and air defense models also were created and given preliminary testing. In the course of

these developments, it became clear that the largest unit which be handled by a human manual control system was a company-team, that even this was barely achievable.

Technology caught up with ES in the mid-to-late 1970's, when the Combat Development Experimentation Command (CDEC) developed an instrumented range at Fort Hunter Liggett, CA. This system was on the use of lasers instead of bullets to make casualty assessm All soldiers and weapons platforms (tank, APC, etc.) were equipp with both lasers rated "eye-safe" and associated detectors. If detector was struck by a laser of the opposing force, a computer a determination of whether the contact was to be considered a destruction, a hit with disability or a near miss. The instrumer range provided an ongoing position location for every major weapc system and vehicle in the exercise, and made it possible to condu detailed after-action reviews. Thus, the research potential of t system was phenomenal. Position location, or "ground truth" information, could be stored in the computer; in addition, every engagement could be recorded on a time-based storage medium. CDE used this range extensively, and still employs it for systems anc concept research.

Laser technology made possible the application of ES to support exercises for units larger than the company-team. TRADOC began t

development of laser applications to training systems in the 1970's, and expanded the technology to include portable laser training systems for use at home stations. These became known as the Multiple Integrated Laser Engagement System (MILES). One serious limitation of the use of MILES is the sophisticated maintenance base or service contract required because of its high technology.

The National Training Center (NTC) at Fort Irwin, CA, is the most sophisticated embodiment of Army combat simulations. Not only does it encompass the state-of-the-art technology in ES, but it also features a permanent aggressor force which performs military operations based on Warsaw Pact tactics. Each combat battalion in the US Army is cycled periodically through the NTC to experience the reality of desert combat without its hazards. The level of realism and stress placed on units at the NTC is considerably higher than anything else they are ever exposed to, short of actual combat.

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The potential uses of simulation in research and Army training are many and diverse. The main advantages of using simulation techniques are lower cost, greater control and higher safety conditions. Cost is particularly relevant with systems in which research and/or training would result in the consumption of costly expendable products, such as aviation fuel or ammunition. Wear and tear on operational systems must also be considered. For example, Orlansky and String (1980)

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conducted a literature survey on the training benefits of flight simulation, and concluded that considerable savings could be achieved by the limited use of flight simulation replacing a number of flight hours. Control in experimental research is essential if results are to be generalized. In this regard, simulation can provide a wide variety of techniques to the researcher. Many operational conditions can be simulated in a laboratory situation. Day can become night; time can be made relative to other conditions; even climatic profiles can be structured and programmed. However, in applied research, care must be taken to insure that the experiment does not reach such a high level of abstraction that results have no application to the "real world". The applied experimenter must walk a fine line between the need to manipulate independent variables and the institutional requirements for providing face validity to use in subsequent fielding of the research products. This is in contrast to the basic researcher, who is not constrained by these needs.

Safety is both an ethical and a practical consideration. Simulation provides an opportunity for creating situations which are critical, yet contain no actual hazard. ES, for example, can create the sights, sounds, and as some have claimed, even the feel of battle, without the dangers of real combat. Anyone who has flown intercepting courses in actual aircraft to evaluate human engineering aspects of collision avoidance devices would attest to the advantages of simulation.

Another advantage of simulation with relevance to research is the potential for measurement. The level of control which the experimenter exerts over the test situation in simulation makes possible many opportunities for behavior measurement which would otherwise be unachievable. Computer-driven simulations offer the possibility of automated data collection. CDEC and NTC both make extensive use of automated techniques to record time-linked unit and individual performance events. Here, however, the experimenter encounters another dilemma. Measurement, if obtrusive, is liable to break the flow of the simulation and distort the measurement situation. Interrupting the flow of a simulation to come in and take data is a distorting influence at best, and should be avoided. Still, trained behavioral observers can be relatively unobtrusive, if the participants in the operation are accustomed to their presence over a reasonable period of time.

This raises again the issue of simulation fidelity. It is an oversimplification to say that fidelity is synonymous with realism. Ideally, a high fidelity simulation should generate the sense of "being there" to the extent that the participants feel that they are a part of the system being simulated. This is not to say that every simulation must have perfect fidelity if it is to be useful.

The level of fidelity of every simulation is a trade-off between cost and expediency. Wi nough money and time, probably any system known

to human beings could be simulated. Hayes (1980) surveyed the literature on training simulation fidelity, and identified two types: stimulus and response fidelity. This is to say that, on the one hand, a simulation may look like a real system, but not provide an opportunity to make real-world responses. On the other hand, the objects, displays or controls in a simulation may not be perfect replications of reality, but what the operator has to do with them is a strong analog to the normal task represented. Hayes concluded that in a training environment response fidelity is most important. This appears to be in substantial agreement with an observation by Fine and Kobrick (1983): "Meaningless tasks performed by untrained subjects inevitably will result in performance decrements even under relatively moderate conditions." (p. 285).

The following anecdote should suffice to describe a near-ideal case of "high fidelity." An Army helicopter pilot described an experience he had while flying a UH-1 simulator at Fort Rucker, AL. These are well-instrumented systems, and sit on a platform with six degrees of motion. Because of this, pilots usually wear seat belts to keep from being thrown about. The pilot in question was flying the UH-1 simulator when a fault was induced. He attempted to make a forced landing and "crashed". Because he had not been wearing his seat belt, he was thrown out of the simulator. He had become so involved in the simulation that later he said: "Man, I looked up - I thought I was dead!"

Another worthy example comes from the era of engagement simulation prior to the advent of laser technology, when stimulus fidelity was only moderate, at best. While out in the New Mexico desert during the development of "Realtrain" for Air Defense Artillery, the senior author spent several days with a Vulcan gun crew. One afternoon, while sitting on a sand dune with a young private who was searching for aircraft, an informal interview was conducted. The soldier commented that his Chaparral-Vulcan battalion had just finished several weeks of field exercises which he felt were made up of boredom and "hurry-up-and-wait." When asked how he felt about ES exercises, he responded: "What I like about this is that when we're out there looking for them, we know that they're out there looking for us." He had been completely absorbed in the simulation and was actively searching for the "enemy."

The importance of simulation as a research tool must be kept in perspective. It is, after all, only a means to an end, rather than an end in and of itself. An effective simulation must place human participants in a realistic situation or operational environment where they can perform their actual duties. This behavior will be a function both of what they bring with them (skills, knowledge, abilities, motivation), and the contingencies established by the situation. By balancing the fidelity required to get the job done against the operating cost to achieve it, researchers and trainers can

create settings which motivate participants and allow them to perform their tasks as they would in the real world. The relevance and applicability of the results for Army operations will speak for themselves.

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